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A COMPARATIVE STUDY OF CERTAIN TYPICAL FOODS BAKED IN THE
ELECTRONIC OVEN, THE CONVENTIONAL OVEN, AND THE
COMBINATION (ELECTRONIC AND CONVENTIONAL) OVEN

by

LaRae Bartholomew Chatelain

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Household Economics and Management

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I wish to express my sincere appreciation to my major professor and advisor, Dr. Louise J. Peet. Dr. Peet not only suggested this investigation and guided its progress, but also by her example enlightened my time spent at Utah State University and by association made it most pleasant.

I also wish to thank Edith Nyman, Ruth W. Hayden, Jane Lott, Frances Taylor, Bernice Nelson, Janel Dayton, Carma Stembridge, Charlotte Brennand, and Eleanor Wein for serving as members of the taste panel.

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LaRae B. Chatelain

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ABSTRACT

A Comparative Study of Certain Typical Foods Baked in the
Electronic Oven, the Conventional Oven, and the
Combination (Electronic and Conventional) Oven

by

LaRae Bartholomew Chatelain, Master of Science

Utah State University, 1968

Major Professor: Dr. Louise J. Peet

Department: Household Economics and Management

Comparative performance of the electronic, conventional, and combination (electronic and conventional) ovens was studied in the preparation of five typical foods: baked custard, lemon cake, baked potatoes, orange marmalade tea loaf, and roast chicken.

The data collected included final temperature of each food and ratings of each food by a taste panel.

Foods prepared electronically and by the combination method required significantly less time with the exception of lemon cake. Foods prepared by the combination and conventional methods were preferred by the taste panel over foods prepared electronically with the exception of custard which was rated superior to custard cooked conventionally.

(58 pages)

INTRODUCTION

The history of food preparation prior to 1945 has shown little change, at least in principle. It all began by the introduction of heat energy from open fires into food by either conduction or by convection currents. Progress since those early days has been measured by certain refinements or improvements in convenience in the source of the heat. Recently the cooking method has reached full cycle by a return to the open fire in the modern backyard or patio barbecue.

The advent of radar in World War II and the subsequent development of microwave technology which allows one to produce high intensity sources of microwave radiation offered an alternative to the other methods of cookery, even in principle. By selective absorption of microwave energy and subsequent thermalization of this energy by food substances, one has a heat source in the food itself. This selective absorption of microwaves offers mixed blessings. On the one hand one need not heat the food containers, oven, and to a lesser degree the kitchen itself, but on the other hand selective absorption by different foods and components within the same food presents problems.

The microwave oven has not yet received wide home acceptance, the principal reason, undoubtedly, the initial expense. Institutions such as hospitals, restaurants, schools, and other food service facilities are using them on a regular basis. It is our opinion that

widespread household acceptance awaits only a reduction of production costs, which is inevitable, with increased sales, and also continued research directed toward standardization of operating techniques so that a typical housewife can get predictable results.

It was the purpose of this thesis to select typical foods such as baked custard, lemon cake, baked potatoes, orange marmalade tea loaf, and roasted chicken and prepare them under controlled conditions in a domestic electronic oven, the GE Versatronic. This model can be used also in combination with a conventional source of electric heat. These two methods were further compared with the same foods cooked entirely in the conventional oven. In each case the reproducibility of results was checked.

Throughout this study the following objective was kept in mind:

To compare the cooking time, acceptability, and finished product of each oven method.

The following hypotheses and assumptions will be studied:

1. Many foods cooked in the electronic oven are as acceptable as foods cooked by the conventional method.
2. Foods cooked in the combination electronic and electric oven may be preferred because this oven has the advantage of the speed of the electronic oven and the surface browning of the conventional oven.

REVIEW OF LITERATURE

Theory of Microwave Heating

The elements of the theory of microwave heating as presented here can be found in standard references such as Copson (1962). Articles were reviewed in several popular magazines, but the information was not of a scientific nature and was not considered desirable to include in this review.

Microwave heating is usually included in the general category of "Electronic Heating" which also includes induction heating and dielectric heating. Both of these latter methods are quite distinct. Induction heating is accomplished by eddy currents induced in conducting media by an alternating magnetic field. The low and erratic conductivity of food materials is probably the reason why this method has not been too successful in cooking application.

Dielectric heating is accomplished by an alternating electric field in dielectric media. The electric dipoles (molecules with separation of + and - charges) of the media try to line up with the alternating electric field, and the agitation set up by the oscillating dipoles heats up the media. The "polar" character of the media is of major importance and, in the case of food material, is probably too erratic for optimum results.

The radiation field is produced by accelerated (oscillating) electric charges. The oscillating charges (currents) in the case of low

frequencies can be produced by tuned circuits that one finds in radio transmitters. The higher frequencies that are necessary for radar and electronic oven radiation are produced in magnetron tubes which operate in principle like the tuned circuits of radio transmitters. The frequency limit for these man made oscillators is of the order of 3×10^{10} cycles per second. To get higher frequencies one must use frequencies inherent in molecules (infra-red), atoms (visible light), and nuclei (gamma radiation).

The utility of microwave application lies in the fact that water absorbs microwaves of wave lengths of the order of 5 inches. Most foods contain a high percentage of water and would therefore readily absorb the microwave energy. The absorbed radiation energy reappears as thermal energy (heat), and thus the food itself becomes a source of heat up to the depth of penetration of the microwaves. The two frequencies commonly used in electronic ranges are 2450 MHz and 915 MHz . The majority of the studies carried out have used the 2450 MHz . In this study the electronic oven used was a GE Versatronic which has a frequency of 915 MHz . The depth of penetration depends on the frequency, with high frequencies penetrating less. More efficient heating is possible with volume foods. Bacon and other foods with little depth do not cook rapidly in an electronic oven with a frequency of 915 MHz .

The energy source of the electronic oven consists of a microwave source which is a magnetron tube. The tube converts the energy supplied by the 120 or 240 volt source into radiant energy of 915 MHz or

2450 MHz. This energy is "piped" by means of a wave guide into the oven itself which is cubical in shape with metallic walls. The metal walls confine the radiation to the oven itself and tend to promote standing wave configurations within it. A means of "stirring" the waves with rotating metallic blades or rotating shelf is introduced to break up the standing waves as they would lead to uneven heating. One could, nevertheless, still anticipate uneven heating due to nonuniform absorption (fats and ice are much less absorbent than water) as well as patterns of nodes and antinodes forming within the oven.

Performance Studies of Electronic and Conventional Cooking

A variety of studies have been done with the electronic range in comparing food products cooked electronically with those cooked by conventional means. In an early study Bollman et al. (1948) reported vegetables cooked electronically compared favorably in acceptability with those cooked by conventional methods if special techniques were used. In a later study Fenton (1957) stated that there was no consistent trend in either method of cooking for all quality factors of any one food. Surface appearance more often than flavor was scored low. Gordon and Noble (1959) reported that in comparisons made of the flavor, color, and ascorbic acid retention in vegetables of the cabbage family using the electronic range and conventional methods, those cooked in the electronic range had a higher retention of ascorbic acid while those cooked

by conventional methods were milder in flavor and retained a greener color.

Fox and Dungan (1968) found that for satisfactory cooking of vegetables electronically just enough water was added to create a steam atmosphere in the covered container and that the microwaves went directly into the vegetables and cooked them from the inside as the steam atmosphere cooked them from the outside. They also noted that the microwaves were most efficient for reheating foods.

The advantage of speed in baking potatoes in the electronic oven was reported by Goldsmid (1967). Loads from one to capacity (13) were baked. One small potato required 2 1/2 minutes, and even though the time increased with the load the total time for a capacity load was far less than required by the conventional oven. Flavor and texture of microwave baked potatoes were considered excellent by taste tests. The potato skin was soft, rather than dry and crusty as was the case in a conventional oven. He noted that in more than 150 tests he saw no need to pierce the skin of the potato to avoid the possibility of skins popping. Copson (1962) reported that "doneness" of a microwave baked potato was defined as the average temperature of 195 F.

In a comparative study on pork patties, roast, and chops Apgar et al. (1959) found cooking conventionally required five times the cooking time of electronic cooking. There was less weight loss in the pork chops cooked electronically, but they were less acceptable because of poor surface color. Marshall (1960) noted a decrease in quality and

quantity of a top round of beef cooked electronically as compared to the conventional range. Headley and Johnson (1960) in a comparative study on lamb roasts reported that roasts were removed at an internal temperature of 150 F and reached a final temperature of 180 F in 15 to 23 minutes of standing. There was greater shrinkage and 8 percent more loss of weight in the roast cooked in the electronic range though it required only one-fourth the time necessary for roasting in the conventional oven. Electronically cooked roasts were judged more well done while those cooked in a conventional oven were juicier and had better lamb flavor. Kylen et al. (1964) in a similar study of meat cookery found the total cooking time for roasts and meat loaves was less for electronic than for conventional cooking. Lower palatability scores were received by the products cooked in the electronic range. The disadvantages of cooking electronically appeared to be due to the adverse effects in color, texture, and flavor. Powers (1965) reported that the results of a taste panel indicated that the electric oven produced meat loaves more evenly done, with a greater degree of "doneness," and more acceptable in appearance than the electronic oven. No significant difference in moisture or flavor was noted. In considering time of operation, cost, fuel utilization efficiency, and drip loss cookery in the electronic oven was superior.

Fox and Dungan (1968) discussed the techniques they believed to be involved in successful microwave preparation of roast beef. The geometry of the roast should be uniform; the roast must be completely thawed; the energy must be cycled into the roast rapidly, and then the

heat allowed to equalize throughout the product, aided by the driving heat of the convection oven. They also noted excellent results with oven fried chicken prepared by using the convection oven in conjunction with the microwave oven. Whole birds were difficult to cook because of their small size, but roasted turkey resulted in a moist product.

In a study comparing acceptability of chicken cooked electronically and conventionally to an internal temperature of 195 F Phillips, Delaney, and Mangel (1960) found that although there was a tendency for scores to be higher for chicken cooked in the conventional oven general acceptability scores showed no significant differences between the two cooking methods. Copson (1962) reported that poultry cooked in the electronic range may appeal to users because of its thorough volume cooking. He noted that finished temperatures were 185 F to 190 F and yielded a pleasant chicken flavor. Copson also observed that red blood cells in chicken bone marrow were not as well stabilized in conventional as in microwave precooking. This was an important quality factor for the partly and fully cooked poultry processing industry. These products are breaded and ready for finishing in the home. Bone discoloration was much better controlled by the volume heating method.

In the GE Versatronic oven cookbook (1966) general directions for poultry state that when the internal temperature taken in the breast of the bird reaches 165 F it is sufficiently cooked. This is considerably lower than a previous reference recommended for a final temperature.

Van Zante (1966) described a method in which egg whites were used

for evaluating the distribution of cooking power of different electronic ranges. Coagulated areas of egg white indicated cooking power was more general in distribution in the 2450 MHz electronic ranges than in the 915 MHz electronic ranges where the pattern of coagulation was more concentrated near the central area of the revolving shelf. The problem of smooth and even distribution of electromagnetic waves for cooking within a resonant cavity of small size is simpler for the short wave length. Theoretically the longer wave length should be capable of greater penetration depth and a more even distribution of cooking power within a food. Equalized distribution of cooking power remains a principal problem in the engineering and use of electronic ranges.

Baldwin (1967) noted the effects of microwaves on egg white. He stated that high-protein foods cooked electronically were usually not as acceptable as those cooked conventionally. With electronic exposure, coagulation proceeded from the center to the outside of the albumen; with conventional heat, coagulation progressed from the exterior to the interior. Consumer Bulletin (1968) reported the results of a study using the electronic range to cook several foods. They concluded that certain foods cooked in the electronic range were not satisfactory; foods that use egg white as a leavening agent, souffles, and angel cake, as well as custard should not be cooked by electronic methods.

Neuzil and Baldwin (1962) studied the effect of electronic cookery on cakes mixed by the conventional method. They reported that all cakes cooked electronically tended to be less tender and less moist than

conventional cakes, although cell structure and flavor were not significantly affected. They observed that volume was greater in white cake cooked electronically. These findings did not agree with Street and Surratt (1961) who did a similar study using a yellow cake mix. They found electronically baked cakes more tender and less moist and observed that as the liquid was increased in the batter the volume of the cake decreased and more nearly approached that of conventionally baked cakes. Findings indicated that loss of moisture in the cake during cooking in the electronic range was controlled by the cooking time rather than the amount of liquid in the batter. When the browning unit of the electronic range was used the surface of the cake was dried rather than browned. It was also observed that an increase in the liquid increased the length of the browning period. Kapenekas (1965) reported that a taste panel found electronically baked chocolate cakes dry with compact cell structure. It was suggested in the 915 MHz GE Versatronic cookbook (1966) that quality can be improved by using all purpose flour which results in a thick heavier type batter. The cookbook also indicates that "doneness" of the cake should be checked at the minimum time given because cakes cooked electronically can become "overdone" more easily than when cooked conventionally and that a deep crack is a sign of an overcooked cake. Allaire (1966) noted a difference in heating in the electronic and conventional ovens. When the surface moisture was first removed from foods cooked in the conventional oven the surface overheated and sometimes became sealed or formed an impervious skin or

crust which inhibited the further removal of internal moisture. In the microwave oven, drying occurred where the moisture was located. The internal moisture was heated and a pressure gradient established which caused the moisture to be forced to the surface. The surface remained wet until all moisture was removed.

Copson (1962) discussed a difference in heating in the two frequencies most commonly used for microwave heating. He observed through the use of thermocouple probes that heating at 2450 MHz was "peripheral" heating while at 915 MHz "core" heating occurred. He included graphs that showed how the two frequencies could complement each other (Figure 1). Copson also stated that the effect of greater microwave density is stratification of cake which gives a denser layer in the lower part and a coarser texture throughout.

Fox and Dungan (1968) reported on the field feeding system, Subsistence Preparation by Electronic Energy Diffusion (SPEED), currently under development at the United States Army Natick Laboratory. This system was based on the use of microwaves as a primary source of cooking energy. In 1967 studies were made, and as a result the food preparation was directed towards a system of "integrated cooking" (a combination of electronic and conventional). Integrated cooking used the most efficient aspects of microwave ovens, hot air convection ovens, and electric grills. They were used to complement and supplement each other. Through several engineering innovations, a very uniform energy distribution has been developed within the oven cavity. The microwave

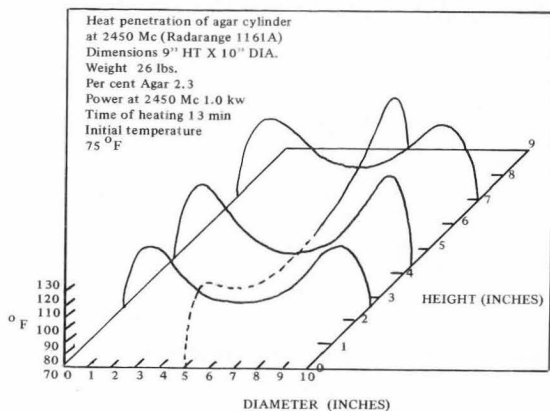


Fig. 11. Three-Dimensional Temperature Gradients in Agar Cylinders Heated at a rate of 30 Kw.-sec./lb. at 2,450 Mc.

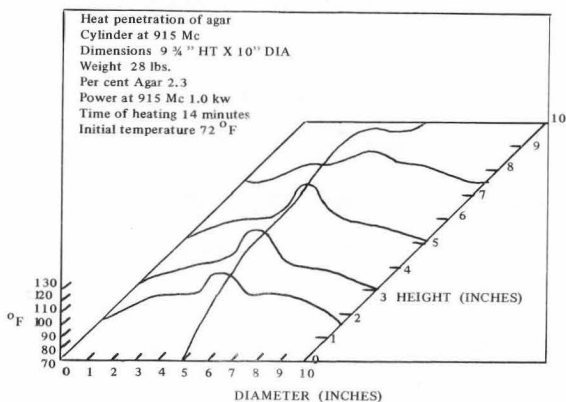


Fig. 10. Three-Dimensional Temperature Gradients in Agar Cylinders Heated at a Rate of 30 Kw.-sec./lb. at 915 Mc.

Figure 1. Comparative penetration of two different microwave frequencies. (By permission from Microwave Heating by David A. Copson, AVI Publishing Company, Inc., Westport, Connecticut)

oven was used primarily to get a large amount of energy (heat) into the product in a short time period. In the SPEED system of integrated cooking only a few items were cooked entirely by microwaves. After the food was heated in the microwave oven, the food was held until the energy had a chance to equalize throughout the product before cooking was completed in the conventional oven. In conventional cooking a time-temperature-weight relationship exists, while in microwave cooking there is a time-energy-weight relationship. In SPEED kitchens cooking instructions have been reduced to kilowatt minutes per pound of product with all ovens calibrated so that exact wattage is known.

Huxsoll and Morgan, Jr. (1968) stated that microwaves can best be used to yield new products or give different product characteristics.

In a study in which agar was used as a medium for absorbing microwave energy Van Zante (1959) reported that microwave power varied from time to time in the same electronic range; the condition of the magnetron, the magnetron current adjustment, voltage extremes, and power tube conditions all affect the actual cooking power. Temperature measuring techniques are evaluated with the recommendations that thermocouples and potentiometers be used for recording temperature immediately after removal from the influence of microwave energy.

In discussing appropriate utensils for use in the electronic ovens Van Zante (1961) stated that the contents of round pans heat more evenly than do the contents of square pans. Also that the contents of glass

utensils heat more quickly than do the contents of earthenware utensils, and a cover on a pan in the electronic range inhibits heating of the contents but may help retain moisture.

PROCEDURE

Design of Study

The purpose of this study was to use three different type ovens in the preparation of certain everyday foods that would be used in the main course of a meal or for dessert. Typical foods were chosen to compare the cooking time, acceptability, and finished product in each oven.

This study was made by using the GE Versatronic range which can be used in three ways: as an electronic oven, conventional oven, or as a combination electronic and electric oven. In the interest of time a separate GE conventional electric range was used for cooking the foods conventionally to facilitate a more uniform standing time of the foods before being served to the taste panel. A large number of foods were prepared in the preliminary study, and five foods were chosen for the final study.

Before any experimental work was performed with the range, the ovens were measured for uniformity of temperature at each temperature indicated in the recipes by using thermocouples of iron and constantan with a potentiometer (Figures 2 through 5). Because the temperature in the GE conventional electric and the electric component of the Versatronic were fairly comparable, it was possible to use the two ranges. A chart for recording the temperatures measured in several areas of each food product by using the thermocouples and potentiometer was

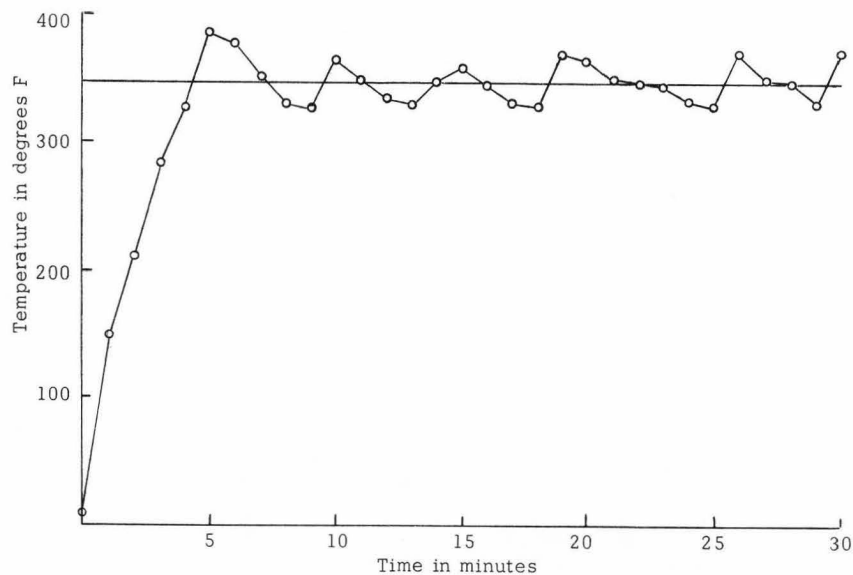


Figure 2. Temperature of GE Versatronic conventional oven at 350 F

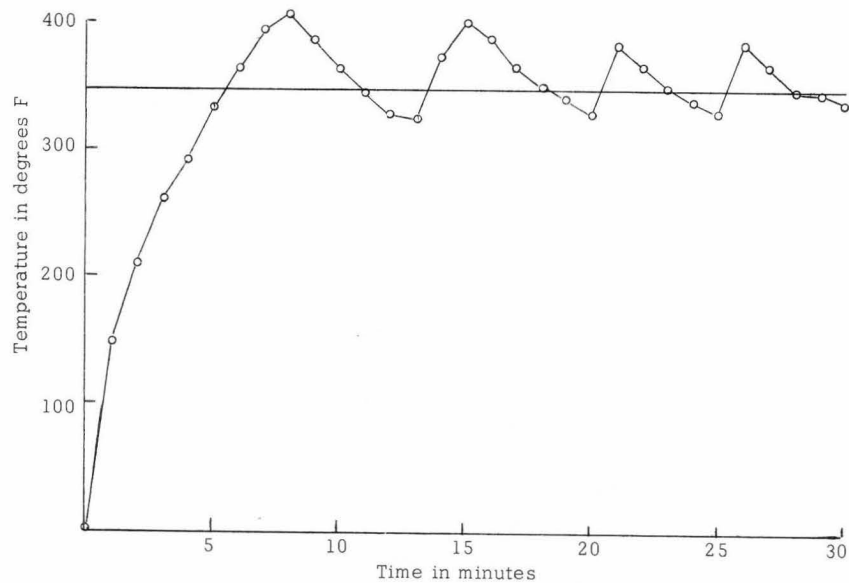


Figure 3. Temperature of GE conventional oven at 350 F

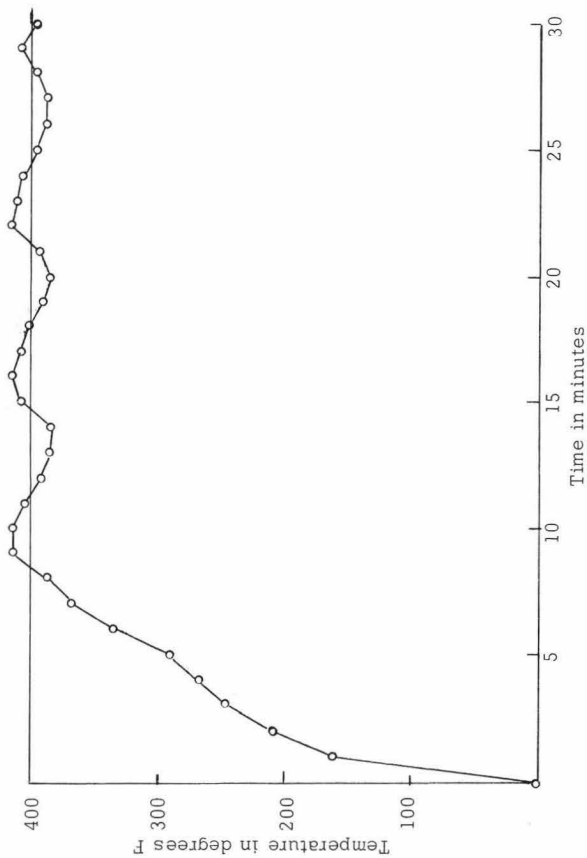


Figure 4. Temperature of GE conventional oven at 400 F

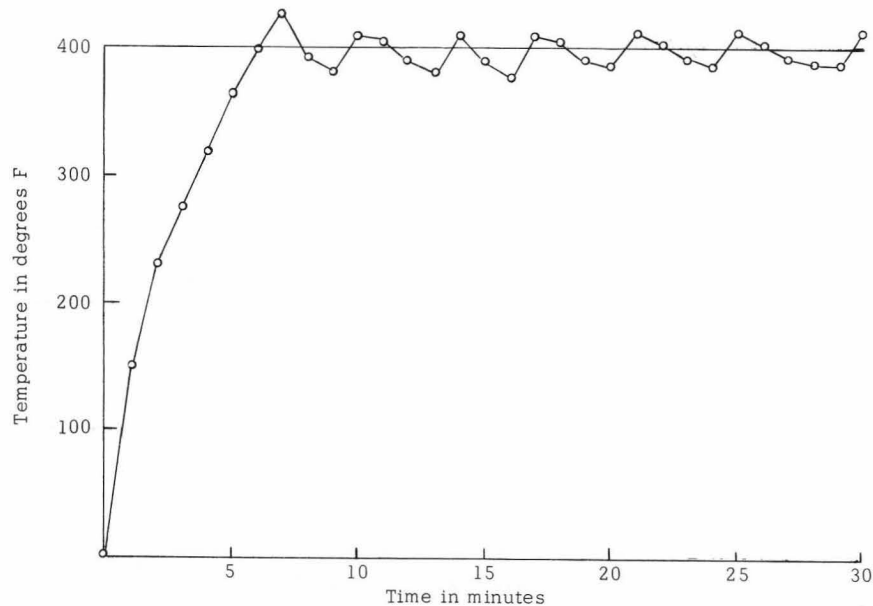


Figure 5. Temperature of GE Versatronic conventional oven at 400 F

developed (Figure 6). Measurements were taken immediately after the product was removed from each oven. A score card was also made for rating each product (Figure 7). A taste panel of Home Economists was chosen to assist in the comparisons.

Equipment Used

GE Versatronic range--General Electric Company model JE896

The range has the following specifications:

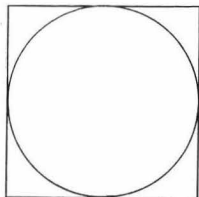
1. Power source: 115/230 or 120/240 volts, 60 cycles, single phase
2. Power consumption

High power		700 watts
Low power		150 watts
Electric oven	Bake	3000 watts
	Broil	3000 watts

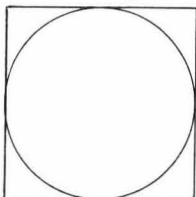
This particular model is described as the Versatronic range, "the world's most versatile cooking center." It is a trim line style and featured in coppertone color with chrome trim. The cooktop is finished with acid resistant titanium porcelain enamel. The oven interior is of gray porcelain enamel. The total height of the Versatronic is 71 1/16 inches. The dimensions of the electronic oven are 21 x 15 x 18 inches. This oven has a rotating shelf that revolves six times a minute for distribution of microwaves when used electronically; the shelf can be removed for conventional cooking.

Use three different type ovens: (1) electronic, (2) conventional (electric), and (3) combination (electronic and electric). Note temperature differences in various areas of food cooked in different type ovens.

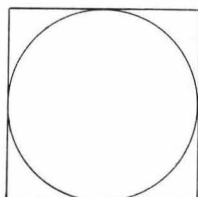
Type of oven:



Electronic Oven



Conventional (electric)
Oven



Combination Oven

Time

Time

Time

Electronic power

Electronic power

Oven temperature

Oven temperature

1. Tenderness

1. Tenderness

1. Tenderness

2. Texture

2. Texture

2. Texture

3. Moistness

3. Moistness

3. Moistness

4. Flavor

4. Flavor

4. Flavor

5. Comments

5. Comments

5. Comments

Use potentiometer to measure temperatures in various areas of foods. Immediately upon removal from oven place thermocouple in several areas of food and record temperature.

Addenda:

1. Name of food _____
2. Type of container _____
3. Comments on desired changes in recipes _____

Figure 6. Temperature measurements

NAME _____ DATE _____ PRODUCT _____			Rating: 5 very acceptable 4 -- 3 acceptable 2 -- 1 not acceptable	
Qualities to be tested:	Tenderness	Texture	Moistness	Flavor
Sample No.				
Comments: _____				

Figure 7. Score card for taste panel

GE Conventional range single oven--General Electric Company, serial PT168961j, model 304T3WH

This range has the following specifications:

1. Power source: 115/230 or 120/240 volts, 60 cycle, A.C.
2. Power consumption

Oven:	Bake	2800 watts
	Preheat	4900 watts

The cooking platform is of acid resistant titanium porcelain enamel bonded to steel. The oven used in this study contains a chrome lined door with a glass window. The interior of the oven is porcelain enamel; the dimensions of the oven are 23 x 16 x 18 inches.

Potentiometer--Leeds and Northrup Company, catalog number 8692

The potentiometer, an indicating type, was used in conjunction with the thermocouple of iron and constantan to measure the temperature in various areas of the food products.

Cooking containers

Pyrex glass baking dishes 13 x 9 x 2 inches

Pyrex glass trivets 8 x 6 x 1/2 inches

1 1/2 quart pyrex round baking dishes 6 x 4 inches

Round pyrex glass baking dishes 8 1/2 x 1 3/4 inches

Pyrex glass loaf dishes 9 x 4 1/2 x 2 1/2 inches

8 ounce pyrex glass custard cups

8 ounce plastic cups

2 cup pyrex glass measuring cups

Records

Score cards

Temperature charts for food products

Method of Procedure

In the preliminary studies the following foods were prepared: macaroni casserole, souffles, scalloped potatoes, pineapple upside down cake, coffee cake, brownies, yellow cake, angel cake, cherry biscuits, meat loaf, chicken, turkey, halibut, chuck roast, weiners, baked potatoes, peas, celery, broccoli, squash, baked apples, scrambled eggs, custards, and butterscotch pudding. The following foods were prepared by reheating: baked potatoes and cherry pie, while squash, chicken, turkey, and halibut were thawed as part of the preparation.

For the final study a plan was made to prepare five representative type foods commonly prepared in the home. The foods chosen for the final study were custard, lemon cake (mix), baked potatoes, orange marmalade tea loaf, and roasted chicken. Three duplicate recipes were prepared, and one was baked in each type oven according to specific directions. The foods were prepared for a second and third time several days apart to prevent possible influence of previous opinion formed regarding the food.

The potentiometer was set up, and immediately upon removing a food

from each oven the temperature of the food was measured for temperature variation using the thermocouple of iron and constantan with the potentiometer.

The taste panel was composed of nine Home Economists, largely faculty and graduate students from the Foods Department, Utah State University, who were experienced in the art of taste panel science. The panel sessions were always at the same hour and in the same room. During the tasting periods the panel members were situated in a large room. The sessions always involved tasting three products, one cooked by each of the three oven methods. Codes used to identify foods were changed often to eliminate association of a letter or number with a particular method of preparation. A glass of water was provided so that there would be a minimum of carry over from one food product to another by taste panel members.

Oven cookery using baked custard

In this study a recipe was used from the recipe book provided for the Tappan Electronic range (1966). Alterations in the recipe necessary for the GE Versatronic are indicated in parenthesis.

Baked Custard

3 eggs	1/4 t. salt
4 T. sugar	1/2 t. vanilla
1 2/3 c. milk	

Scald milk for approximately 2 minutes (4 minutes) with microwave energy on high speed (or to 140 F). Beat eggs slightly, add sugar, salt and vanilla. Gradually add scalded milk. Place in 1 qt. glass casserole. Do not cover with lid. Place casserole in a 2 qt. glass casserole filled with boiling water. Cook about 4 minutes (6 1/2 - 7 minutes) with microwave energy on high speed. (Leave custard standing in boiling water 10 minutes.) Remove from boiling water. Let stand on cake cooling rack. Chill. (Tappan Company, 1966, unpagged)

The distribution of the egg was more effective if a rotary beater was used, however, a large amount of egg foam was produced by the beater. It was found that if the custard was allowed to stand 5 to 10 minutes this foam would disperse, eliminating a possible crusty surface when the custard was baked. The 1 1/2 quart pyrex glass bowl containing the custard was placed in a larger bowl of boiling water immediately before the custard was placed in the oven. Immediately upon removing the custard the internal temperature of various areas in the food were measured at halfway depth using the thermocouple probe of iron and constantan with the potentiometer. The custard was allowed to remain in the hot water for 10 minutes before it was removed to cool. It was served to the taste panel approximately one-half hour after being cooked. The same procedure was followed in the preparation of the custard and treatment after it was baked for each of the three baking methods. The taste panel judged the custards on the basis of tenderness, texture, moistness, and flavor.

The setting and time for baking custard differed with each oven.

Table 1. Comparative times for baking custards by three methods

Oven	Minutes	Power	Temperature
Electronic	6 1/2	high	
Conventional (electric)	38		350 F preheated
Combination	6	high	400 F preheated

Oven cookery using lemon supreme cake
(Duncan Hines mix)

According to the directions the following ingredients were added to the mix: 2 eggs and additional water and flour to compensate for increased altitude. The cake was baked in a 13 x 9 x 2 inch greased pyrex baking dish lined with waxed paper. The internal temperatures of the cakes were measured in various areas using the thermocouple probe with the potentiometer immediately upon removal from the oven. The cake was allowed to stand in the baking dish 10 minutes and then turned out on a rack to cool. All edges, top, and bottom of the cake were trimmed before being served to the taste panel to eliminate the possibility of bias. The taste panel judged the cakes on the basis of tenderness, texture, moistness, and flavor.

Table 2. Comparative times for baking cakes by three methods

Oven	Minutes	Power	Temperature
Electronic	27	high	
Conventional (electric)	25		375 F preheated
Combination	13	high	400 F preheated

Oven cookery using baked potatoes

Three 6 to 8 ounce potatoes were scrubbed, and a small piece was cut from the ends of each potato. The potatoes were evenly spaced on a small pyrex glass trivet and placed in the oven. The position of the potatoes was changed at 5-minute intervals in the electronic and in the combination ovens. Immediately upon removing the potatoes from the oven the internal temperatures at halfway depth were measured at various areas using the thermocouple with the potentiometer. The potatoes were kept warm and served from 15 to 20 minutes after baking was completed in the first oven and immediately upon completion of baking in the second oven. Potatoes were cut into one-half inch slices and served to the taste panel. The taste panel compared the potatoes on the basis of tenderness, texture, moistness, and flavor.

The setting and time for baking potatoes differed with each oven.

Table 3. Comparative times for baking potatoes by three methods

Oven	Minutes	Power	Temperature
Electronic	20	high	
Conventional (electric)	60		400 F preheated
Combination	15	high	400 F preheated

Oven cookery using orange marmalade tea loaf

This recipe was taken from the GE Versatronic cookbook.

Orange Marmalade Tea Loaf

1/4 c. butter	1 1/2 c. unsifted all-purpose
1/4 c. sugar	flour
1 egg	2 t. baking powder
1/2 c. orange marmalade	3/4 t. salt
	1/4 c. orange juice

Place butter, sugar, egg and marmalade in small bowl or mixer. Beat 1 minute, medium speed. Stir flour with baking powder and salt. Add to marmalade mixture in thirds alternately with orange juice in halves, mixing on low speed just until each addition is blended. Spread evenly in greased 9 x 4 1/2 x 2 1/2 inches loaf dish lined with waxed paper. (General Electric Company, 1966, unpagged)

Immediately upon removing from the oven, internal temperatures at halfway depth were measured in each loaf using the thermocouple probe with the potentiometer. The loaf was cooled 10 minutes in the pan as recommended, and then turned on a rack to finish cooling. The edges, bottom, and tops of loaves were trimmed to eliminate possibility of bias. The tea loaf was served to the taste panel about one-half hour after

being removed from the oven. The taste panel judged the tea loaf on the basis of tenderness, texture, moistness, and flavor.

The setting and time for baking the tea loaf differed with each oven.

Table 4. Comparative times for baking tea loaf by three methods

Oven	Minutes	Power	Temperature
Electronic	8	high	
Conventional (electric)	35		350 F preheated
Combination	7	high	400 F preheated

Oven cookery using roasted chicken

Three 3-pound chickens were washed, drained, and each placed on a saucer in a round pyrex baking dish. The chickens were turned over after 10 minutes in the electronic and combination ovens, and turned after 30 minutes in the conventional oven. Immediately upon removal from the oven, the internal temperature was measured in several areas with thermocouple probe and potentiometer.

The setting and time for roasting chicken differed with each oven.

Table 5. Comparative times for roasting chickens by three methods

Oven	Minutes	Power	Temperature
Electronic	20	high	
Conventional (electric)	70		350 F preheated
Combination	20	high	350 F preheated

Analysis of Data

The score cards of taste panel members were tabulated to evaluate the differences in acceptability of foods cooked by the three methods.

The record of internal temperature variations of foods cooked by the three methods was compared with taste panel preference of foods to determine possible relationship.

RESULTS AND DISCUSSION

The recipes, preparation, and cooking time for each food have been listed with the Method of Procedure.

Oven Cookery Using Baked Custard

Electronic oven

The custard reached an optimum internal temperature of 175 F in 6 1/2 minutes in the electronic oven. A delicate flavor and a firm smooth texture were produced at this temperature when the custard was allowed to remain standing in the hot water for 10 minutes after being removed from the oven. The Versatronic time control is not equipped to time for less than 1 minute. There was a very fine line between the effect of 6 1/2 minutes which was usually the optimum time and 7 minutes which resulted in an overbaked custard. It did not seem possible to duplicate exactly each time; the oven seemed to have heat variation from time to time.

After standing, some small amount of separation was evident in the custard. It was not syneresis in the usual sense but a medium thin liquid that might be descriptive of a thin "stirred" custard. The separation occurred on the bottom of the baking dish and was considered acceptable. This custard was acceptable even after being held for three days under refrigeration.

Conventional electric oven

This custard was judged the least acceptable. It was baked for 35 minutes in a 350 F oven and did not set up well. There was some evidence of syneresis. The custard was most acceptable when baked in a preheated 350 F oven for 38 minutes without opening the oven for testing during the baking time. The internal temperature in the center was 175 F and slightly higher on the sides. The custard set up well when it was allowed to remain standing in hot water 10 minutes. Upon standing there was a small amount of syneresis, and the custard was not considered acceptable after being refrigerated three days. The texture was less smooth and more firm than the other methods. Egg flavor was pronounced.

Combination (electronic and electric) oven

An excellent custard was baked in a preheated 400 F oven for 6 minutes with the electronic oven set on high power. This custard reached an internal temperature of 175 F, and the container was allowed to remain 10 minutes in hot water. When baked for 5 minutes, the custard had a slightly grainy quality which was not noticeable when baked an additional minute. This custard had a "stirred" custard flavor and a firm smooth texture. There was also a small amount of separation unlike syneresis but a medium thin liquid found on the bottom of the baking dish. This custard was acceptable even after being stored under refrigeration for three days.

Summary

Contrary to a previous publication, Consumer Bulletin (1968), acceptable custards can be prepared in the electronic range. There was no appreciable difference in the acceptability of the two methods, electronic and combination electronic and electric, baking a satisfactory custard. The timing is crucial, and duplication of flawless baking is not always possible because of heat variations in the same range. However, the custards baked by these two methods were considered excellent and superior to the custard baked in the conventional electric oven.

Table 6. Relation of temperature variation to acceptability rating of baked custards

Oven method	Temperature variation degrees F		Acceptability rating ^a
	Number	High-low	
Electronic	7	(184-177)	4.28
Conventional	11	(175-164)	3.91
Combination	13	(184-170)	4.30

^a Rating: 5 very acceptable

4 --

3 acceptable

2 --

1 not acceptable

Oven Cookery Using Lemon Supreme Cake(Duncan Hines Mix)Electronic oven

The cake was made with a mix according to directions on the package and baked in a 9 x 13 x 2 glass baking dish lined with wax paper. Flavor, texture, and uniform cells were noted in the center of the cake, however, the area around the edges remained uncooked after 20 minutes at high power. In 27 minutes of baking on high power a final internal temperature of 203 F was reached to obtain a fairly dry exterior. The interior retained fine texture but was somewhat dry and rated third choice in overall scoring.

Conventional electric oven

The recommended time for this cake was 25 minutes in a 375 F preheated oven. The texture was rated only medium fine, and in certain areas there were some holes. The lemon flavor was pronounced. This cake was rated second, but there was only a slight difference in the scores of the cakes cooked in the combination and the conventional ovens. An internal temperature of 196 F was reached at the center of the cake with 201 F at the edges.

Combination (electronic and electric) oven

An excellent cake was baked in 13 minutes using the electronic setting on high power and the electric component preheated to 400 F.

The internal temperature in the center of the cake reached 203 F. The cake had a fine texture, delicate flavor, and high volume. These cakes consistently developed a large crack running the length of the cake. The GE Versatronic Oven Manual (1966) suggests that this is the result of overbaking and also suggests that the use of all purpose flour might eliminate this problem. Even though this cake was scored low on moistness, the overall rating of the taste panel placed it first.

Summary

The combination, using the advantage of the speed of electronic heating and the surface drying caused by the electric component, resulted in 13 minutes in an excellent large cake with a delicate flavor and fine texture. Even though this combination cake rated first with the taste panel, it rated only slightly higher than the cakes baked by the other two methods.

Oven Cookery Using Baked Potatoes

Electronic oven

Three 6 to 8 ounce potatoes were baked at the same time on high power. The potatoes were placed on a pyrex glass trivet dish and turned at 5-minute intervals. The internal temperature of the potato was 203 F. The taste panel judged these potatoes too moist with a soft skin. These potatoes scored somewhat lower but were still acceptable.

Table 7. Relation of temperature variation to acceptability rating of lemon supreme cake

Oven method	Temperature variation degrees F		Acceptability rating ^a
	Number	High-low	
Electronic	32	(194-162)	4.21
Conventional	10	(197-187)	4.22
Combination	20	(203-183)	4.31

^aRating: 5 very acceptable

4 --

3 acceptable

2 --

1 not acceptable

Conventional electric oven

The method was repeated using three 6 to 8 ounce potatoes placed on a pyrex glass trivet dish in a preheated oven of 400 F for 1 hour. The potatoes were not turned. The internal temperature after 1 hour was 203 F in the center and 202 F in other areas. The potatoes in overall scoring rated only one point lower than the combination method which was rated first.

Combination (electronic and electric) oven

The electronic oven was set on high power for 15 minutes, and the electric component was preheated to 400 F. Three 6 to 8 ounce potatoes were baked at the same time on a pyrex glass trivet dish and turned at

5-minute intervals. The potato skin was crisp and slightly brown with the interior of the potato judged mealy. The internal temperature at the center of the potato was 204 F with only one point variation in other areas. This potato was preferred over those baked electronically but scored only one point above the potato baked by conventional means.

Summary

There seemed to be some relationship between temperature variation and acceptability. The combination and conventional methods resulted in potatoes that scored highest and had only 1 degree of variation in temperature between the different areas of the potato. These were rated highest, while the potatoes cooked electronically rated somewhat lower had from 2 to 16 degrees of variation in different areas where temperature was measured.

Table 8. Relation of temperature variation to acceptability rating of baked potatoes

Oven method	Temperature variation degrees F		Acceptability rating ^a
	Number	High-low	
Electronic	8	(203-195)	4.05
Conventional	10	(203-193)	4.24
Combination	3	(204-201)	4.25

^aRating: 5 very acceptable

4 --

3 acceptable

2 --

1 not acceptable

Oven Cookery Using Orange Marmalade Tea Loaf

Electronic oven

The first loaf was baked at high power for 15 minutes. This resulted in a well baked loaf with the outside surface dry. The internal temperature of the center was 234 F. When the loaf was cut it was evident that it was overbaked because the center was a dark color. The second loaf was baked with the time reduced to 10 minutes. This loaf was also overdone with an internal temperature in the center of 212 F. The third loaf was baked for 8 minutes at high power and reached 206 F internal temperature in the center of the loaf. This loaf was judged acceptable by the taste panel, but had a tendency to dry out rapidly.

Conventional electric oven

The loaf baked by conventional means was preferred because of its moist quality. It was baked in an oven preheated to 350 F for 35 minutes. The way in which this loaf baked demonstrated the effect of moisture being sealed inside by surface heating, noted by Allaire (1966). The surface was brown and well done while the center remained very moist. The internal temperature in the center was 202 F; the temperature went up to 207 F on the sides of the loaf.

Combination (electronic and electric) oven

The loaf was baked 7 minutes in an oven that was preheated to 400 F with the electronic setting on high power. This loaf was well baked

with a golden brown color and good volume. The internal temperature was 213 F, and when cut the loaf showed a dark center. It was acceptable but considered dry and compact. The overcooked interior of this loaf would support the "core" heating theory that Copson (1962) suggests is evident in electronic ranges with the frequency of 915 MHz.

Summary

The orange marmalade tea loaf baked by conventional means was preferred by the taste panel. The high rating was attributed to the quality of moisture in the loaf. The electronic and combination methods of cooking resulted in an overbaked dry product that was only partially acceptable.

Table 9. Relation of temperature variation to acceptability rating of orange marmalade tea loaf

Oven method	Temperature variation degrees F		Acceptability rating ^a
	Number	(High-low)	
Electronic	37	(218-181)	2.81
Conventional	13	(207-194)	4.05
Combination	16	(219-203)	3.15

^aRating: 5 very acceptable

4 --

3 acceptable

2 --

1 not acceptable

Oven Cookery Using Roasted Chicken

Electronic oven

The electronic oven was set on high power for 20 minutes. The 3-pound chicken was placed breast side up on a saucer in a pyrex glass baking dish and turned over after 10 minutes of baking. After 20 minutes the chicken was removed from the oven and the temperature measured by using the thermocouple of iron and constantan with the potentiometer. There was variation in temperature between the right and left side of the breast which would indicate the heating was not uniform. The GE Ver-satronic cookbook (1966) suggests that an internal temperature of 165 F taken in the breast indicates the chicken is sufficiently baked. The temperatures measured were somewhat higher. There was no browning, and the juice was pink in color. The meat was rated tender and acceptable.

Conventional electric oven

The 3-pound chicken was placed breast side up on a saucer in a pyrex baking dish and roasted for 70 minutes in the oven preheated to 350 F. The chicken was turned after 30 minutes. When removed the chicken had a crisp golden brown color; a small amount of browned fat remained in the baking dish. This chicken was preferred by the taste panel. The rating was only slightly higher than the rating given the chicken cooked by the combination method. There was considerable variation in the temperature measured in different areas of the chicken. The skin was removed from the chicken and the meat cut into pieces to

eliminate possible bias when served to the taste panel.

Combination (electronic and electric) oven

The chicken cooked by the combination method was baked for 20 minutes on high power in a preheated oven of 350 F. The 3-pound chicken was placed breast side up on a saucer in a pyrex glass baking dish and turned over after 10 minutes. There was little browning and little juice. The skin was crisp. The taste panel rated this chicken as tender, the white meat less tender than the dark meat. This chicken was rated second although the difference in scoring was too small to be important.

Summary

The variation in the temperatures measured in different areas of the chicken occurred in chickens cooked by all three of the methods. The lack of, or extent of, temperature variation did not seem to relate to the preference expressed by the taste panel for a chicken cooked by a particular method. Chickens were cooked by the electronic and combination methods in 20 minutes; the conventional method required 70 minutes. The chicken cooked in the electronic oven was rated somewhat lower. The skin was removed from the chicken and the meat cut into pieces to eliminate possible bias when served to the taste panel. There was no measurable difference in the scoring of the taste panel between the chickens cooked by the combination and conventional methods. They were both rated tender with a good chicken flavor.

Table 10. Relation of temperature variation to acceptability rating of roasted chicken

Oven method	Temperature variation degrees F		Acceptability rating ^a
	Number	High-low	
Electronic	38	(198 - 160)	4.27
Conventional	31	(192 - 161)	4.47
Combination	20	(204 - 184)	4.44

^aRating: 5 acceptable

4 --

3 acceptable

2 --

1 not acceptable

SUMMARY AND CONCLUSIONS

The purpose of this study was to use three different ovens in preparation of certain everyday foods that would be used by a typical housewife in preparation of family meals.

In this particular study a GE Versatronic was used because it provided for all three methods of cooking. However, in the interest of time the oven of a separate GE conventional electric range was used for baking the foods by the usual method. Preliminary to food preparation, oven temperatures of the GE conventional and the conventional component of the Versatronic oven were measured with iron constantan and a potentiometer to establish a basis of comparison.

The study consisted of the preparation of five foods: baked custard, lemon cake, baked potatoes, orange marmalade tea loaf, and roasted chicken using the three methods of oven cookery.

The data collected in each part of the study included temperature measurements in various areas of each food as soon as the food was removed from the particular oven and ratings of each food by the taste panel.

There was no appreciable difference between the custards cooked by the electronic and the combinations methods. The custards reached an internal temperature of 175 F in 6 to 6 1/2 minutes, had a smooth firm texture, and delicate flavor. These custards were acceptable after three days

of refrigeration. The conventional custard required a longer time to reach 175 F which seemed to be optimum. This custard was less acceptable; the texture was less smooth, and there was some syneresis.

The lemon cake cooked in the electronic oven required 27 minutes to reach an internal temperature of 203 F. This temperature was reached by the conventional method in 25 minutes and in 13 minutes by the combination method.

There was no measurable difference between the rating of the electronic and the conventional methods; the combination method was given preference by the taste panel. The edges were all trimmed from the cakes so the taste panel was not influenced by the moist exterior of the electronically baked cake. This cake had a fine texture and delicate flavor, but unlike most foods cooked electronically this cake required more time to bake than did the cake baked conventionally. The conventionally baked cake had a medium fine texture with some holes, a desirable moistness, and a good flavor while the combination method produced a cake with a very fine texture and good flavor but lacked moistness.

Three 6 to 8 ounce potatoes baked in the electronic oven in 20 minutes were somewhat characteristic of boiled potatoes with soft skin and a moist interior. In the combination oven the three potatoes required only 15 minutes to yield a crisp brown skin and a mealy interior. The potatoes baked in the conventional oven had crisp skin and mealy to moist interior. The difference in rating given by the taste panel to the combination and conventional methods was slight. The potatoes baked

in the electronic oven were rated somewhat lower but were still acceptable.

The orange marmalade tea loaf baked in the conventional oven required four times longer, but was preferred by the taste panel for its quality of moistness and flavor. The electronic and combination baking both resulted in a loaf that was fine in texture, bland in flavor, and tended to dry out rapidly. The loaf baked by the combination method was acceptable, but the loaf baked electronically rated 2.81 which was below the acceptable rating of 3.00.

The chicken baked in the conventional oven required three times longer to bake but was golden brown with a crisp skin. The white meat was scored less tender than the dark meat. Both the electronic and combination methods required 20 minutes to bake. The meat was scored tender, but there was little browning. There was a wide variation in the temperature in the different areas of the chicken. There was no noticeable difference in the ratings of the taste panel for the chickens cooked by the conventional and combination methods. The chicken cooked in the electronic oven scored somewhat lower but was considered acceptable.

Foods cooked in the electronic oven were consistently rated somewhat lower than foods cooked by the other two methods. There was no measurable difference in ratings of custards in the electronic and combination ovens or in lemon cakes cooked by the electronic and conventional methods. The orange loaf was considered less acceptable when cooked in electronic and combination ovens than by conventional means.

The chicken and potatoes were both considered more acceptable when baked by conventional and combination methods than by electronic methods. See Table 11.

Table 11. Summary of ratings of taste panel

Food	Oven methods		
	Electronic	Conventional	Combination
Baked custard	4.28	3.91	4.30
Lemon cake	4.21	4.22	4.31
Baked potatoes	4.05	4.24	4.25
Orange marmalade tea loaf	2.81	4.05	3.15
Roasted chicken	4.27	4.47	4.44
Total	15.62	20.89	20.45

There was less variation in temperature in the custard and potatoes than was found in the cake and chicken. Perhaps this was because there is a higher water content in the potatoes and custard than is found in cakes.

The electronic oven cooked the food 2 to 10 times faster than the conventional oven, but some foods were considered less acceptable than when prepared in the conventional oven.

The combination method consistently resulted in an acceptable product in all cases, and usually there was no very noticeable difference

between this product and the products prepared in the conventional oven.

The combination oven has the advantage of the speed of the electronic component and the surface cooking advantage of the electric component.

RECOMMENDATIONS FOR FURTHER STUDY

This study has raised certain questions and suggested further studies that would aid in a more complete understanding and efficient use of electronic ranges. The recommendations are:

1. A study comparing the effect of the two frequencies: 915 MH_z and 2450 MH_z on the foods used for this study.
2. A study to develop recipes of greater reliability and variety for use with the electronic range.
3. A similar study using conventional gas ranges for a comparison with the electronic range.
4. A similar study preparing additional food products for comparison by the three methods: electronic, conventional, and combination ovens.
5. A comparative study of cost and convenience of use of the electronic, conventional, and combination ranges.
6. An investigation of the wavelength penetration in various foods.
7. The development of a more accurate system of temperature measurement within the electronic range so that the pattern of heat distribution could be studied.

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